The Critical Role of Cloud Drop Effective Radius >14 Micron Radius in Rain Initiation

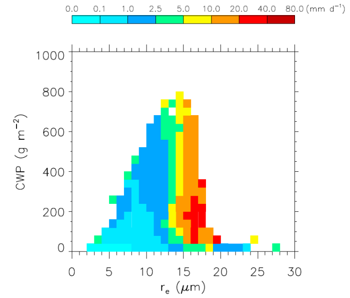
Research Highlight

Rain initiation is a critical event in the life cycle of clouds, as it starts the downdraft that replaces the updraft that formed the cloud in the first place and leads to its eventual dissipation. In marine stratocumulus (MSC) the formation of heavy drizzle leads to their breakup and a transition from a full cloud cover to regime of open cells. This is associated with a large decrease in the cloud radiative effect.

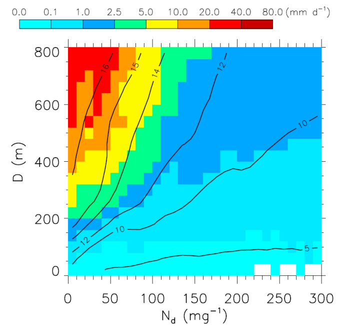
Scientists at Pacific Northwest National Laboratory and the Hebrew University of Jerusalem found that the start of rain in marine stratocumulus clouds is determined by the number of nucleated cloud drops and the depth above the cloud base that is required for cloud drops to reach an effective radius of 12–14 micrometers. They analyzed numerical simulations described in previous studies showing that adding aerosols to these clouds can prevent their breakup from closed into open cells. The researchers also noted a clear dependence of rain intensity on cloud-top drop effective radius, which holds irrespective of cloud water that can be significantly depleted by intense rain, weakening its role in determining rain properties.

The analysis produced an internally consistent and unified interpretation of the roles of aerosols and cloud water in initiating drizzle in non-precipitating clouds and further intensification of the rain. Previously, scientists have demonstrated that the aerosols and their effect on precipitation can be responsible for the transition between regimes of open and closed cells, and that the intense drizzle in the marine stratocumulus and associated dynamical feedbacks are responsible for the self-organization of open cells. The model-based insights from this research indicate that sufficiently large concentrations of aerosols (to keep cloud-top drop effective radius from reaching 14 micrometers) can prevent significant drizzle even in thick and water-laden marine stratocumulus and prevent their breaking into open cells.

The rain intensity in MSC was often ascribed mainly to the liquid water path (LWP). While this remains true for precipitating clouds, this research shows that rain does not start before the cloud-top effective radius (Re) exceeds 12 to 14 micrometers. This is determined by the number of nucleated cloud drops near cloud base, which, in turn, is determined by the aerosol cloud drop nucleating properties and cloud base updraft. This provides a simple and powerful way to parameterize the impacts of aerosols on clouds and precipitation properties.



The dependence of rain rate on cloud drop effective radius (re) near cloud top. The color scale is for the median value of column maximum rain rate in each joint bin of CWP-re (cloud liquid water path and cloud-top re).



The dependence of median value of column maximum rain rate (in color scale) and cloud drop effective radius (re) on cloud depth (D) and cloud drop number concentrations (Nd) near cloud base.

Reference(s)

Rosenfeld D, H Wang, and PJ Rasch. 2012. "The roles of cloud drop effective radius and LWP in determining rain properties in marine stratocumulus." Journal of Geophysical Research – Atmospheres, 39, doi:10.1029/2012GL052028.

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Cloud-Aerosol-Precipitation Interactions